Dedicated to my beloved Grandparents

(L) Letlun & (L) Anem

Declaration by the Candidate

The thesis entitled "**Biochemical and Functional Characterization of Ethnomedicinal Plants of Manipur for Development of Functional Food Product**" is being submitted to School of Engineering, Tezpur University in partial fulfilment for the award of the degree of Doctor of Philosophy in the Department of Food Engineering and Technology is a record of bonafide research work accomplished by me under the supervision of Prof. Laxmikant Shivnath Badwaik.

All helps from various sources have been duly acknowledged.

No part of the thesis has been submitted elsewhere for the award of any other degree.

Date: 24/11/2024 (**Ms. Nemnunhoi Haokip)**

Place: Tezpur Registration No. TZ16711 of 2016

TEZPUR UNIVERSITY

Certificate of the Supervisor

This is to certify that the thesis entitled "**Biochemical and Functional Characterization of Ethnomedicinal Plants of Manipur for Development of Functional Food Product**" submitted to School of Engineering, Tezpur University in partial fulfilment for the award of the degree of Doctor of Philosophy in the Department of Food Engineering and Technology is a record of research work carried out by Ms.Nemnunhoi Haokip (Roll No. FPP16001) under my supervision and guidance.

All helps received by her from various sources have been duly acknowledged.

No part of the thesis has been submitted elsewhere for award of any other degree.

Signature of Supervisor

Dr. Laxmikant S. Badwaik

Professor

Department of Food Engineering and Technology

Tezpur University,

Napaam-784028,

Assam, India

Signature of Co-Supervisor

Dr. Raj Kumar Duary

Professor

Department of Dairy Science and Food Technology

Banaras Hindu University,

Varanasi

Date: 12/11/2024

Place: Tezpur, Assam

Acknowledgements

I am expressing my sincere thanks to my Supervisor (s), Dr. Laxmikant S. Badwaik, Professor, Department of Food Engineering and Technology, Assam, and Dr. Raj Kumar Duary, Professor, Department of Dairy Science and Food Technology, Banaras Hindu University, Varanasi, for their consistent guidance during my thesis work. I am highly obliged to receive consistent support that helped me in exploring innovative ideas and successfully implemented it in my thesis.

I express my deepest gratitude to Professor Shambu Nath Singh, Vice-Chancellor, Tezpur University, Tezpur, Assam for providing me with the facilities to carry out my thesis work.

I am highly grateful to Prof. Partha Pratim Sahu, Dean, School of Engineering and Prof. S. C. Deka, Controller of Examinations, for their constant support throughout my thesis work.

It is a great pleasure, and gratitude goes to my Doctoral Committee members, Dr. Robin Doley, Professor, Department of Molecular Biology and Biotechnology, Tezpur University, Dr. Sankar Chandra Deka, Professor, Department of Food Engineering and Technology, and External Research Committee, Dr. Dilip Datta, Professor, Department ofMechanical Engineering, Dr. Tarun Kumar Maji, Professor, Department of Chemical Sciences.

I also duly acknowledge to Departmental Research Committee chairperson and Head of Department of Food Engineering and Technology, Tezpur University, Dr. Laxmikant S. Badwaik, Professor for the continuous support.

I am also thankful to all faculty members, Dr. Charu Lata Mahanta, Dr. Manuj Kumar Hazarika, Dr. Brijesh Srivastava, Dr. Poonam Mishra, Professor, Dr.Nishant R.S. Hulle, Dr. Tabli Ghosh, Dr. Nikhil C. and Dr. Soumya Ranjan Purohit, Assistant Professor of Department of Food Engineering and Technology, Tezpur University for their important suggestions that boosted me up at many phases during my research and thesis writing.

My sincere thanks to the technical staff, Dr. Dipankar Kalita, Dr. Arup Jyoti Das, Mr. Labadeep Kalita, and Mrs. Swdwmsri Mashahary and non-technical staff, Mr. Krishna Borah and Mr. Anjan Keot of the Department for giving the essential assistance during my

research work and formal work in the Department of Food Engineering and Technology, Tezpur University, Tezpur, Assam. I also extend my gratitude to the technical staff, Mr. Prakash Kurmi, Mr. Tridib Ranjan Nath and Mr. Nava Kr. Gogoi of Sophisticated Analytical Instrumentation Centre (SAIC).

I am grateful to University Grant Commission (UGC, New Delhi) for providing UGC-JRF Fellowship (UGC-Ref. no.: 1374/(ST) (NET-JUNE 2015) during my research work.

I extend my heartfelt thanks to my former labmates, Lopamudra Sarma, Preeti Sarkar, and Pallab Kumar Borah and as well as my friends Mr. Manas Jyoti Das, Ms. Sangita Muchahary, Ms. Maibam Baby Devi, Mrs. L. Monika Devi, Mrs. Salai and Mrs. S. Khurshida. I am equally grateful to my Labmates Ms. Ruchi Rani, Ms. Indrani Chetia, Mr. Thoithoi Tongbram, and Mr. Akuleti Saikumar—and to all the research scholars and students whose steadfast support and encouragement have been the foundation of my journey throughout my PhD.

Next, I would like to thank my partner James Sonkholal Mate. Your votes of confidence kept me going when my spirits dipped. I couldn't have done this without you. I also extend my deepest gratitude to my esteemed well-wishers MomonNu, ZakamNu, HeoMong, HeoLienpu, Dikshita Dowerah, Anutee Dolley, Gorishmita Borah, and Mate's family whose steadfast presence and thoughtful words have consistently been a wellspring of strength and encouragement. I am profoundly grateful to my cherished besties Miriami, Mary, Kimi, Chankim, Laxmi, Smita, Bemcy, Shelly, and Rose, whose unwavering support and boundless love have illuminated my life and made every moment infinitely richer. Finally, my sincere gratitude to my parents (Jamkholun and Lhaiboi), Godparents (Neikim and Seithang), Aunty Boisi, nephew (Khaviv Momon) and my siblings (Bebem, Thangmin, Boipi, Naolien and Goupu) for the constant motivation during the entire duration of my PhD. Each of you has played a vital role in my life, and your collective support has made all the difference. I am deeply grateful for your friendship and the incredible strength you have given me. Knowing that I have such amazing people in my corner fills me with hope and gratitude.

Forever grateful to God, the Almighty, who has given me with innumerable blessings, knowledge, and opportunities, so that I have finally been able to complete the thesis.

Nemnunhoi Haokip

LIST OF TABLES

LIST OF FIGURES

List of Abbreviations

µg	Microgram
µm µmol	Micrometer
3D	Three dimensional
a*	Redness
ABTS	2,2'-azino-bis 3-ethylbenzothiazoline-6-sulphonic acid
$A_{control}$	Absorbance of control
Al	Aluminum
ANOVA	Analysis of variance
A_{sample}	Absorbance of sample
ATCC	American type culture collection
Av	Average
b*	Yellowness
Ca	Calcium
CCD	Central composite design
cm	Centimeter
Co	Cobalt
CO_2	Carbon dioxide
Cu	Copper
CV	Coefficient of variation
df	Degree of freedom
DPPH	2,2-diphenyl-1-picrylhydrazyl
DPP-IV	Dipeptidyl pepdidase-IV
EDTA	Ethylenediamine tetraacetic acid
EE	Encapsulation efficiency
FCR	Folin-Ciocalteau reagent
Fe	Iron
$FeCl_3$	Iron (III) chloride
$FeSO_4$	Iron sulfate or ferrous sulfate
FRAP	Ferric reducing ability of plasma

FTIR	Fourier transform infrared spectroscopy
g	Gram
GAE	Gallic acid equivalent
GC	Gas chromatography
h	Hour
H	Hydrogen atom
H_2SO_4	Sulfuric acid
HCl	Hydrochloric acid
IC_{50}	Half maximal inhibitory concentration
IR	Infrared
K	Potassium
kHz	Kilohertz
kJ	Kilo joule
L*	Lightness
LC	Liquid chromatography
LPS	Lipopolysaccharide
M	Molarity
m/z	Mass by charge
MAE	Microwave assisted extraction
mg	Milligram
mm	Millimeter
Mn	Manganese
MSE	Mean square error
MTT	3-(4, 5-dimethylthiazolyl-2)-2, 5-diphenyltetrazolium bromide)
MUFA	Monounsaturated fatty acid
n	Number
N	Normality
Na	Sodium

Na_2CO_3	Sodium carbonate
Na_2WO_4	Sodium tungstate
ND	Not detected
NH_4OH	Ammonium hydroxide
Ni	Nickel
nm	Nanometer
O	Oxygen atom
OA	Overall acceptability
OH	Hydroxide
p	p-value
ppm	Parts per million
Q	Quercetin
QE	Quercetin equivalent
R^2	Correlation coefficient
RE	Release efficiency
RMSE	Root mean square error
RP-HPLC	Reversed phase-high performance liquid chromatography
rpm	Rotation per minute
RSM	Response surface methodology
RT	Retention time
s	Second
SCFE	Supercritical fluid extraction
SD	Standard deviation
SEM	Scanning electron microscopy
t	Time
TFC	Total flavonoid content
TPC	Total phenolic content
UAE	Ultrasound assisted extraction
UV	Ultraviolet
W	Watt
w/v	Weight by volume

w/w	Weight by weight
wb	Wet basis
XRD	X-ray diffraction
α	Alpha
θ	Theta